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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
07/578,515	08/16/1990	GEORGE E. MATICH	GEC-0462	3617

21904 7590 07/12/2006

VENABLE
1201 NEW YORK AVENUE
SUITE 1000
WASHINGTON, DC 20005-3917

EXAMINER	
SOTOMAYOR, JOHN B	
ART UNIT	**PAPER NUMBER**
3662	

DATE MAILED: 07/12/2006

Determination of Patent Term Extension or Adjustment under 35 U.S.C. 154 (b)

(application filed prior to June 8, 1995)

This patent application was filed prior to June 8, 1995, thus no Patent Term Extension or Adjustment applies.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 07/06) Approved for use through 04/30/2007.

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NOTICE OF ALLOWANCE AND FEE(S) DUE

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07/578,515	08/16/1990	GEORGE E. MATICH	GEC-0462	3617

TITLE OF INVENTION: RANGING SYSTEMS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1400	$0	$0	$1400	10/12/2006

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THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
07/578,515	08/16/1990	GEORGE E. MATICH	GEC-0462	3617

TITLE OF INVENTION: RANGING SYSTEMS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1400	$0	$0	$1400	10/12/2006

EXAMINER	ART UNIT	CLASS-SUBCLASS
SOTOMAYOR, JOHN B	3662	342-145000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
   - ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
   - ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
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   1 ____________
   2 ____________
   3 ____________

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

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(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

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- ☐ Issue Fee
- ☐ Publication Fee (No small entity discount permitted)
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- ☐ A check is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number ____________ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.
- ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

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Notice of Allowability	**Application No.** 07/578,515	**Applicant(s)** MATICH ET AL.	
	Examiner John B. Sotomayor	**Art Unit** 3662	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *the Secrecy Order rescind rendered June 15, 2006*.
2. ☒ The allowed claim(s) is/are *1,2 and 5-8*.
3. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☐ All b) ☐ Some* c) ☐ None of the:
   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

4. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
   1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☒ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☐ Information Disclosure Statements (PTO-1449 or PTO/SB/08), Paper No./Mail Date _____
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application (PTO-152)
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☐ Examiner's Amendment/Comment
8. ☐ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

John B. Sotomayor
Primary Examiner
Art Unit: 3662

Notice of References Cited	Application/Control No. 07/578,515	Applicant(s)/Patent Under Reexamination MATICH ET AL.	
	Examiner John B. Sotomayor	Art Unit 3662	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-5,023,888 A	06-1991	Bayston, Thomas E.	375/239
*	B	US-5,047,780 A	09-1991	Dijkstra, Jan A.	342/145
*	C	US-5,337,052 A	08-1994	Lohrmann et al.	342/68
*	D	US-5,347,281 A	09-1994	Lewis et al.	342/160
*	E	US-5,731,782 A	03-1998	Walls, Raymond John	342/145
*	F	US-5,898,401 A	04-1999	Walls, Raymond John	342/82
*	G	US-6,211,812 B1	04-2001	Chiles et al.	342/145
*	H	US-6,225,943 B1	05-2001	Curley et al.	342/137
*	I	US-6,628,228 B1	09-2003	Matich et al.	342/75
*	J	US-6,977,611 B1	12-2005	Crabb, Ronald T.	342/122
*	K	US-6,989,783 B1	01-2006	Matich et al.	342/145
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N	GB 2303509 A	02-1997	United Kingdom	MATICH et al.	
	O	GB 2303754 A	02-1997	United Kingdom	MATICH et al.	
	P	GB 2305323 A	04-1997	United Kingdom	WALLS, RAYMOND JOHN	
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

(12) UK Patent Application (19) GB (11) 2 303 509 (13) A

(43) Date of A Publication 19.02.1997

(21) Application No 9004277.1

(22) Date of Filing 26.02.1990

(30) Priority Data
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(51) INT CL^6
G01S 13/32 7/35

(52) UK CL (Edition O)
H4D DRPR DSPE D265 D376
U1S S1839

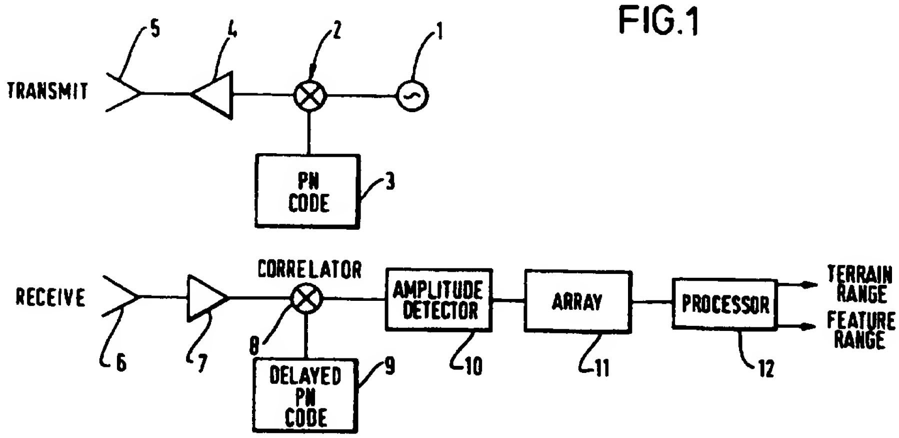
(56) Documents Cited
GB 2122449 A GB 1509464 A US 4758839 A
IEE Proceedings, Vol.133, Part F, No. 2, April 1986, pages 176-186; B. Barboy "Cell-averaging...."

(58) Field of Search
UK CL (Edition K) H4D DRPB DRPE DRPR DSPB DSPE DSPS DSPU
INT CL^5 G01S
Online : WPI, CLAIMS, INSPEC

(54) **Multiple target ranging system**

(57) A continuous wave ranging system comprises a modulator 2 for modulating an r.f. carrier wave in accordance with a pseudo-random code 3, a transmitting antenna 5 for radiating the modulated signal towards a target, a receiving antenna 6 and receiver 7 for detecting the signal reflected back from the target. A correlator 8 correlates the reflected signal with a transmitted code with a selected phase shift 9 corresponding to the current range gate to be tested. In the altimeter described means 10, 11, 12 process the range/amplitude data (Fig 4) from the correlator 8 to discriminate between reflections due to the ground and those due to other features above the ground. Range (R2 Fig 4) to the ground is determined using an area algorithm (Fig 3) based on returns about the greatest amplitude, while range (R1 Fig 4) to the features is based on interpolation at the shortest range producing returns above a threshold.

FIG.1

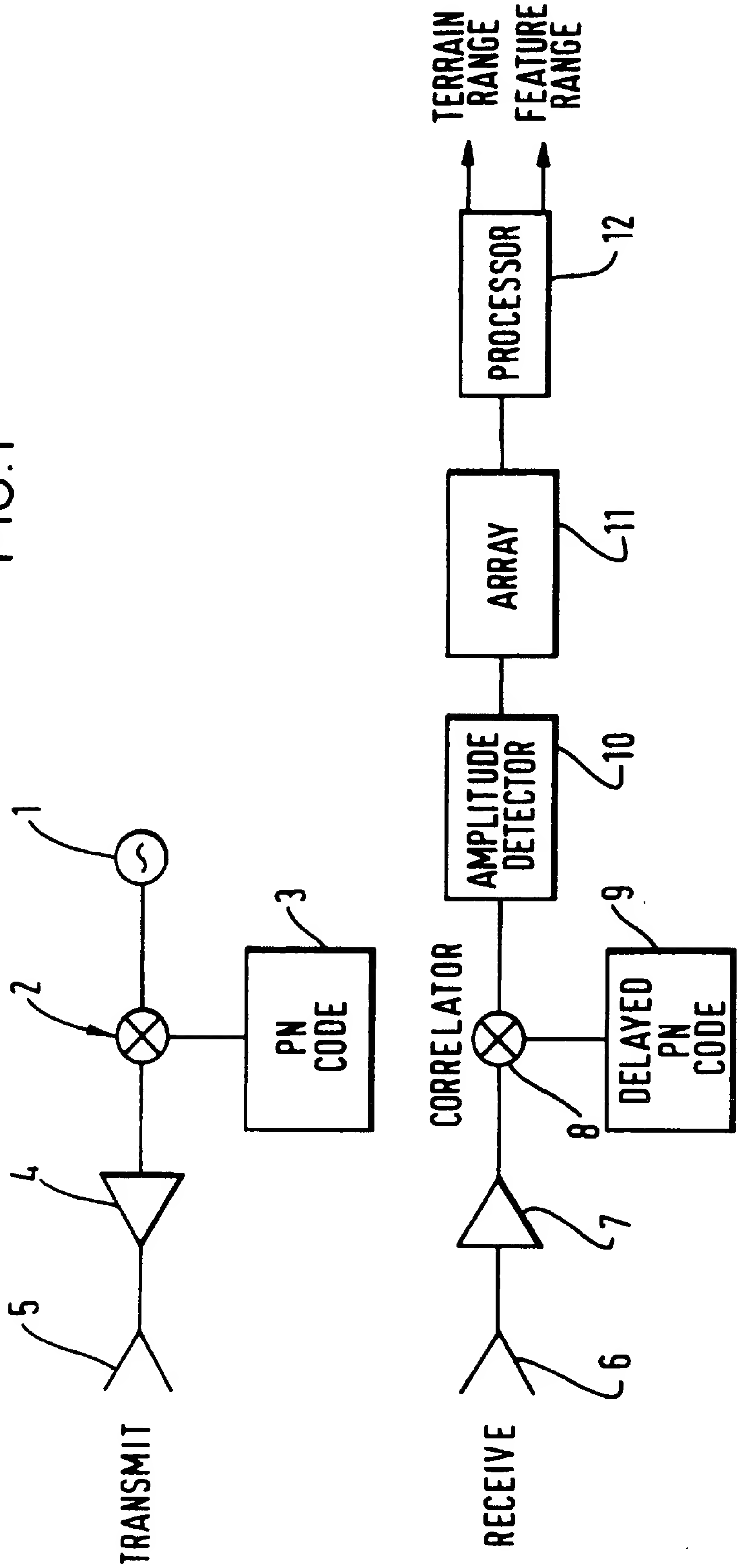


GB 2 303 509 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

1/4

FIG.1


TRANSMIT
5
4
2
1
3
PN CODE
RECEIVE
6
7
CORRELATOR
8
DELAYED PN CODE
9
AMPLITUDE DETECTOR
10
ARRAY
11
PROCESSOR
12
TERRAIN RANGE
FEATURE RANGE

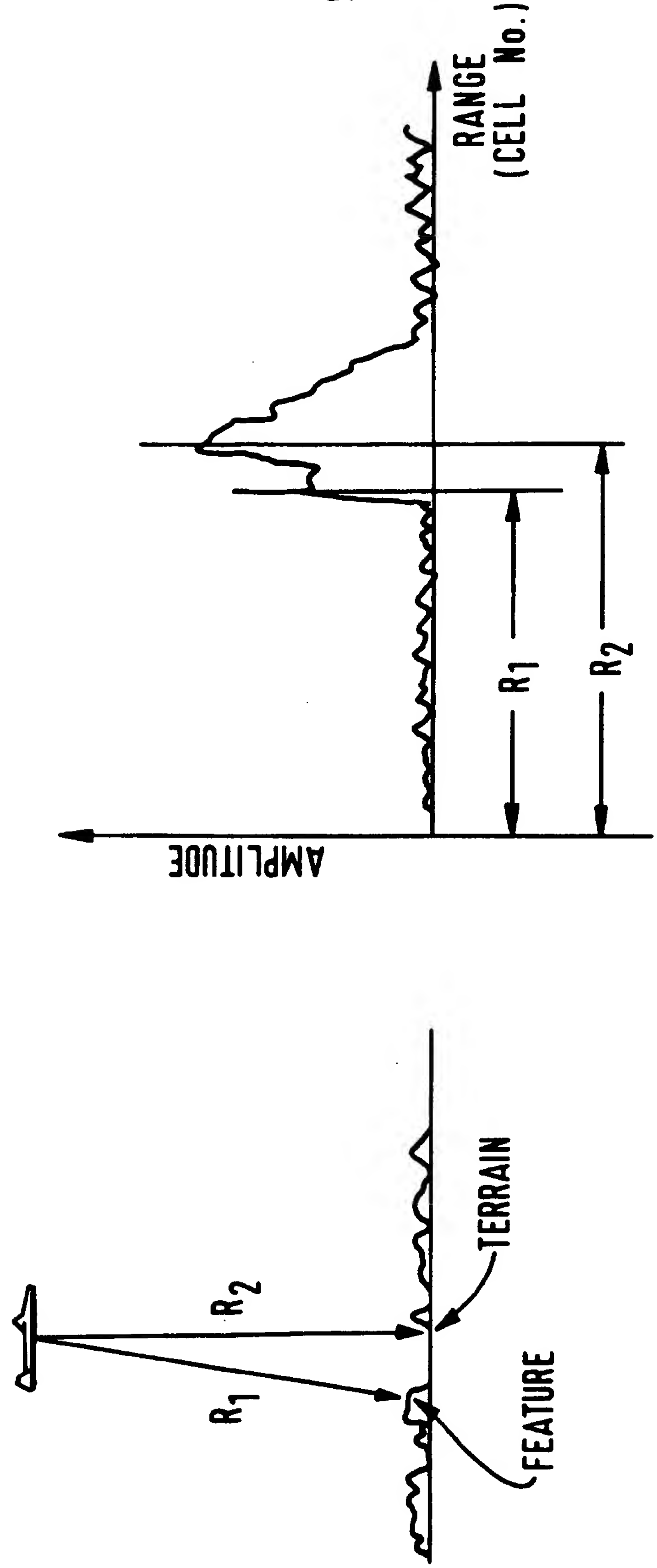


FIG.2

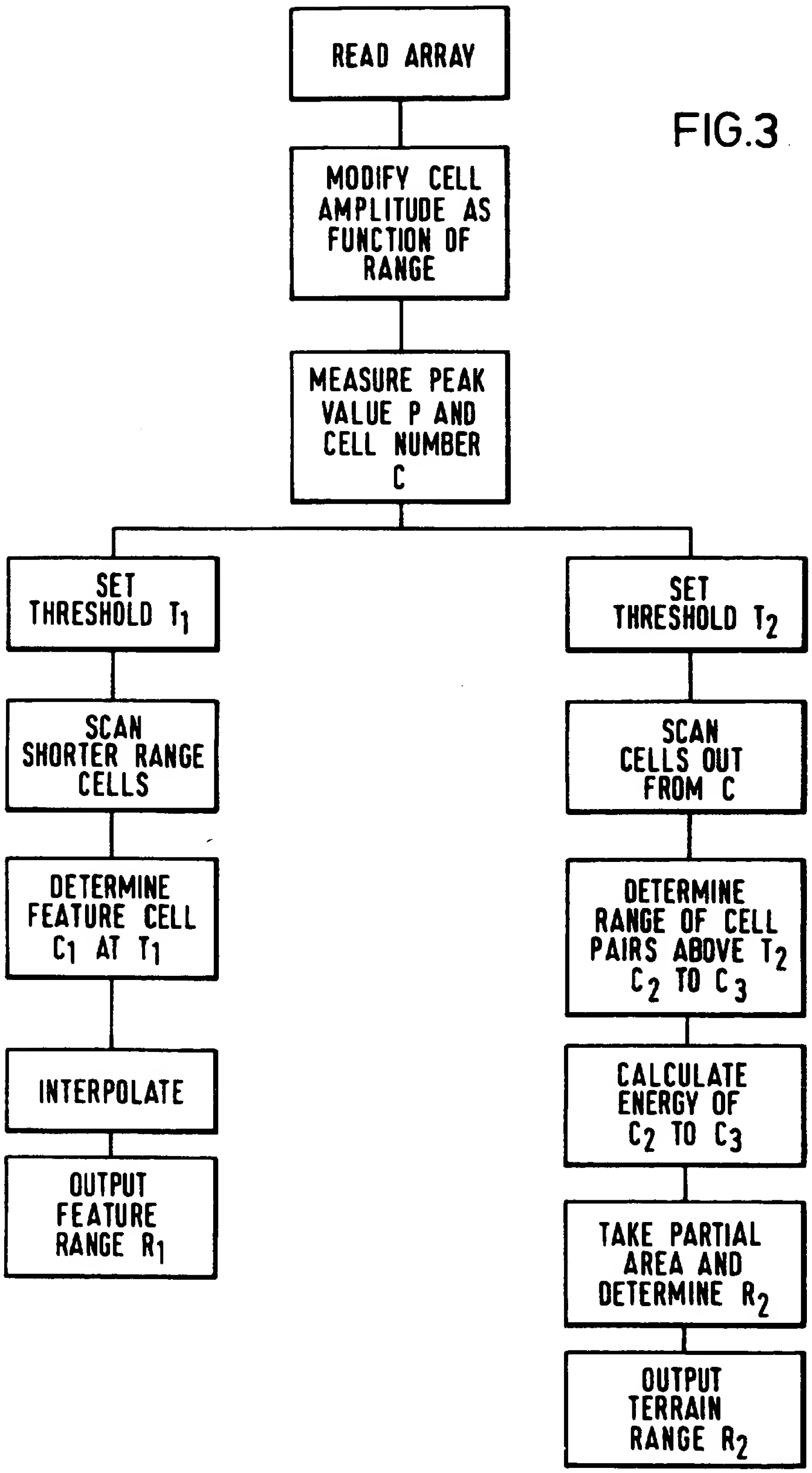
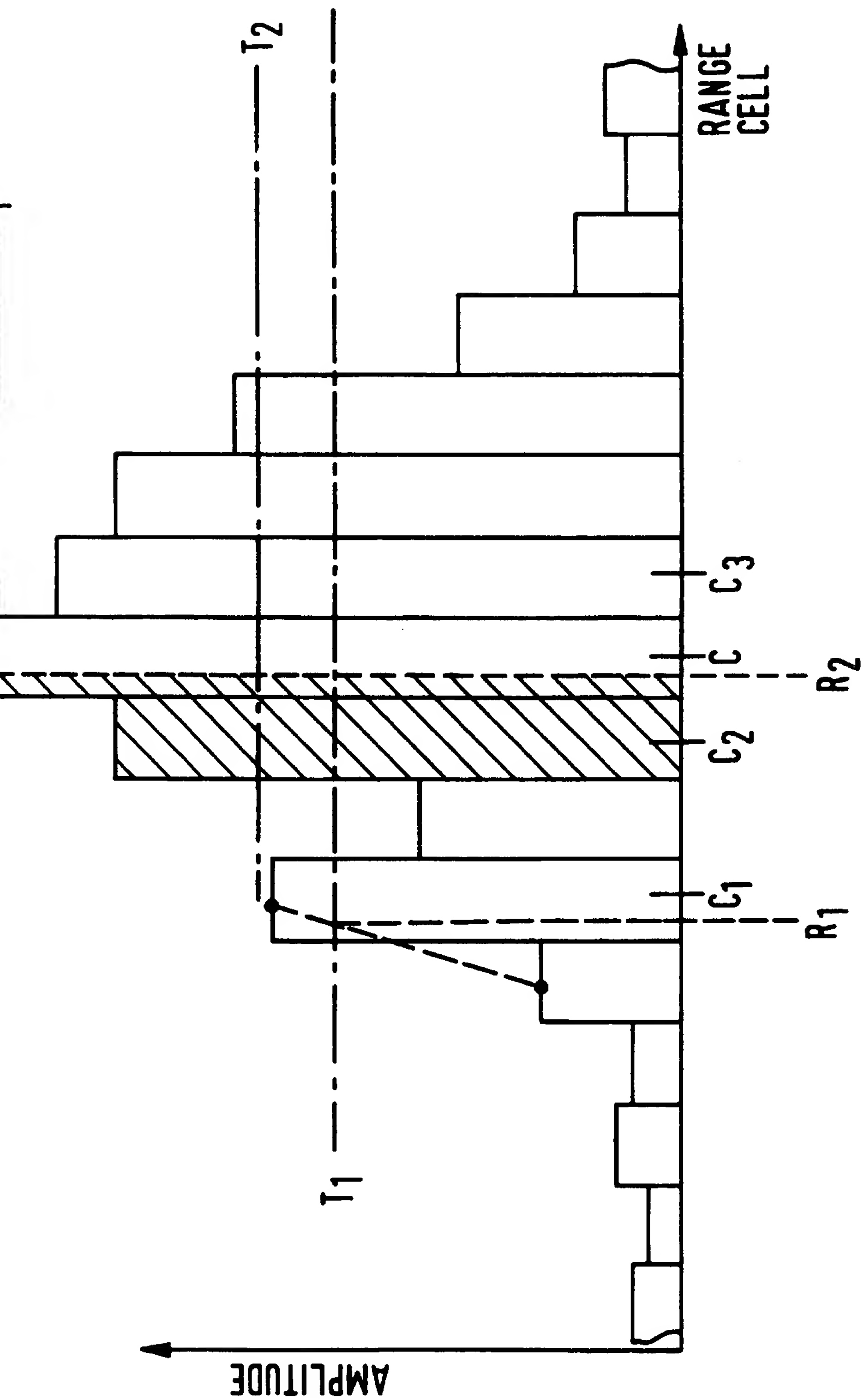


FIG.3

ALGORITHM FOR EXTRACTION OF FEATURE AND TERRAIN RANGES

FIG. 4



2303509

MULTIPLE TARGET RANGING SYSTEM

This invention relates to a continuous wave ranging system and, in one aspect, to an aircraft radar altimeter system.

Such systems usually comprise a means of microwave transmission upon which some form of coding has been added, and antenna for directing the energy to the target, an antenna for receiving the returned energy and, after amplification, a means of determining the amount of delay that has occurred on the signal, and hence the range of the target. The coding on the transmission had in the past been pulse or frequency modulation, but more recently phase modulation from a pseudo-random code has been used. This form of modulation has the property of producing a noise-like transmitted spectrum which is difficult to detect and hence finds applications where covertness is of importance. Covertness can be enhanced by reducing the transmitted power such that the returned signal is just sufficient for ranging measurement.

In such phase-modulated systems, the received

signal is correlated with a delayed version of the transmitted code, the delay being gradually increased in steps, and samples of the output of the correlator are detected and stored in an array. From this stored data, the delay, and hence the range, where the received signal return occurs can be found.

Existing direct sequence spread spectrum ranging systems use techniques such as delay locked or Tau dither loops to track target ranges. These techniques result in a narrow tracking window and tracking loops with excellent dynamic performance. However, the narrowness of the tracking window restricts the ability of such systems to see any targets at ranges other than that being tracked.

According to the invention, a continuous wave ranging system comprises a modulator for modulating an r.f. carrier wave in accordance with a pseudo-random code, a transmitting antenna for radiating the modulated signal towards a target, a receiving antenna and receiver for detecting the signal reflected back from the target, a correlator for correlating the reflected signal with the transmitted code with a selected phase shift corresponding to the current range gate to be

tested, and means for processing the range/amplitude data from the correlator to discriminate between reflections due to the target and those due to other objects adjacent to the target.

The pseudo-random code used in the invention is preferably a maximal length code, a sequence of numbers generated by a shift register with certain feedbacks on it. For the system of the present invention, a code length of 2047 digits is preferred.

The present invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 shows a schematic view of a system according to one embodiment of the inventor,

Figure 2 shows a diagrammatic view of the application of the system and a typical signal received from such a system,

Figure 3 shows one algorithm from the extraction of feature and terrain ranges from the system, and

Figure 4 shows a typical signal reading divided into range cells.

Referring now to Figure 1, the system shown therein comprises a transmitter having a signal generator 1; a modulator 2 for modulating the signal in accordance with a pseudo-random code; a transmitter amplifier 4 and a transmitter antenna 5. A receiver includes a receiver antenna 6; a receiver amplifier 7, a correlator 8 for correlating the received signal with a delayed version of the pseudo-random code 9 according to the range being determined; an amplitude detector 10; a memory array 11 and a processor 12 for analysing the signal stored in the array 11 to determine terrain and feature ranges.

A range scanning technique be used in the above system, where the receiver code is preferably dwelled at a given delay (range) for a fixed integration period enabling signal strength to be measured for each delay period. In turn a picture of signal strength versus range is constructed for the entire measurement range of the system in the array 11. This picture will thus contain signal/range data for all targets as well as environment noise information, a typical result being shown in Figure 2. From this picture, the predominant

target range (terrain) R2 and less dominant shorter ranged targets (feature) R1 may be extracted by use of the processor 12. In order to formulate a robust predominant target extraction technique, regard must be given to target dynamics. It can be shown that a partial area algorithm applied about the predominant target range can significantly discriminate this target from shorter range returns which occur close to it.

One particular method of extracting feature and terrain ranges will now be described with reference to Figures 3 and 4.

Referring now to Figures 3 and 4, the array of amplitudes or signal strengths in the various range bands or range cells is read and the amplitudes are modified to compensate for the law of signal strength versus range, signals reducing at 9 dB/octave due to propagation factors. The cell with the largest amplitude (after compensation) is noted (C) and the amplitude value measured (P).

The method of determining the range of a feature is as follows (left hand side of Figure 3):-

A threshold (T1) is set at a fixed value below P. This is typically 12 dB and a check is made that T1 is above the general noise level. A scan is made of the cells below C starting at a fixed number of cells below C. Typically the scan would start at the equivalent of 300 feet below C although a scan would not normally cover the first few cells, corresponding to ranges below say 15 feet. The cell having the shortest range which has energy above T1 is determined (C1). Interpolation is then made based on the energy in C1 and the energy in the next cell below and from this interpolation R1 is calculated as the range where the T1 threshold is crossed and after filtering is output.

The method of determining the range of the terrain is as follows (right hand side of Figure 3):-

A threshold (T2) is set at a fixed value below P. This need not be the same as T1 but is typically 12 dB when a good signal to noise ratio is obtained. Under poorer signal to noise conditions the threshold will be closer to P. A scan is then made of pairs of cells, comprising one cell in above C and the other below, both by the same amount. When energy in either cell of the scanned pair falls below T2 the scanning is halted. The

range of pairs of cells (C2 - C3) that have energy above T2 is determined. (In the example of Figure 4 only the adjacent pair of cells meets this criterion). The energy in the range of cells C2 - C3 is calculated and the area that contains a fixed fraction K of the total energy in C2 - C3 is calculated, its upper boundary giving the value of R2 (see Figure 4). Typically a value of K is 0.375. After filtering R2 is output as the range to the terrain. The amount of filtering applied to the terrain output can be greater than that of the feature if required.

Thresholds T1 and T2 are chosen so that features such as trees and buildings are accepted and measured whilst returns from clouds and chaff are ignored.

CLAIMS

1. A continuous wave ranging system, comprising a modulator for modulating an r.f. carrier wave in accordance with a pseudo-random code, a transmitting antenna for radiating the modulated signal towards a target, a receiving antenna and receiver for detecting the signal reflected back from the target, a correlator for correlating the reflected signal with a transmitted code with a selected phase shift corresponding to the current range gate to be tested, and means for processing the range/amplitude data from the correlator to discriminate between reflections due to the target and those due to other objects adjacent to the target.

2. A system as claimed in claim 1, wherein a first threshold is determined with regard to the amplitude of the received signals such that the signals immediately above this threshold are signals returned from one or more of said other objects.

3. A system as claimed in claim 1 or 2, wherein a second threshold is set such that an analysis of the energy distribution of so returned signals above said second threshold allows determination of said target range.

4. A system as claimed in any preceding claim, wherein the target is the ground and the other objects are features on the ground.

5. A system as claimed in claim 2, wherein an increasing range scan is made of returned signals from below the range of maximum returned signal strength until the returned signal strength is above the first threshold.

6. A system as claimed in claim 3, wherein a scan is made of pairs of signals above and below the range of maximum returned signal strength until one of said pairs includes a signal below the second threshold, the total energy of the pairs above said threshold is calculated, and the range of a fixed fraction of said total energy determined.

Amendments to the claims have been filed as follows

1. A continuous wave ranging system, comprising a modulator for modulating an r.f. carrier wave in accordance with a pseudo-random code, a transmitting antenna for radiating the modulated signal towards a target, a receiving antenna and receiver for detecting the signal reflected back from the target, a correlator for correlating the reflected signal with a transmitted code with a selected phase shift corresponding to the current range gate to be tested, and means for processing the range/amplitude data from the correlator to discriminate between reflections due to the target and those due to other objects adjacent to the target so as to produce respective range output signals corresponding to the target and to other objects.

2. A system as claimed in claim 1, wherein a first threshold is determined with regard to an amplitude of the received signals such that signals immediately above this threshold are signals returned from one or more of said other objects.

3. A system as claimed in claim 1 or 2, wherein the target range is determined by setting a second

threshold and analysing the energy distribution of returned signals above said second threshold.

4. A system as claimed in any preceding claim, wherein the target is the ground and the other objects are features on the ground.

5. A system as claimed in claim 2, wherein an increasing range scan is made of returned signals from below the range of maximum returned signal strength until the returned signal strength is above the first threshold.

6. A system as claimed in claim 3, wherein a scan is made of pairs of signals above and below a range of maximum returned signal strength until one of said pairs includes a signal below said second threshold, the total energy of the pairs above said threshold is calculated, and the target range determined as the upper boundary of the area that contains a fixed fraction of said total energy.

12

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
9004277

Relevant Technical fields

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Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES WPI, CLAIMS, INSPEC

Search Examiner

G A McLEAN

Date of Search

23 AUGUST 1990

Documents considered relevant following a search in respect of claims
1 - 6

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
Y	GB 2,122,449 A (LICENTIA) - especially pages 3 - 6	1, 3, 4
Y	GB 1,509,464 A (SPERRY) - especially lines 6 - 39, page 2; claim 1	1, 4
X, Y	US 4,758,839 (McDONNEL) - especially column 4	1 - 4
Y	IEE Proceedings, Vol. 133, Part F, No. 2, April 1986, pages 176 - 186 B. Barboy et al "Cell-averaging ..." - especially Sections 1. - 5.	"

SF2(p)

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H4D DRPR D265 D376
U1S S1839

(56) Documents Cited
GB 2202329 A GB 1504118 A GB 1246142 A
GB 1140590 A US 4219812 A

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UK CL (Edition K) H4D DRPB DRPE DRPR DSPB DSPS DSPX
INT CL^{5} G01S
Online : WPI, CLAIMS, INSPEC

(54) **Ranging systems**

(57) A continuous wave ranging system, comprises a modulator 2 for modulating an r.f. carrier wave in accordance with a pseudo random code, a transmitting antenna 5 for radiating the modulated signal towards a target, a receiving antenna 6 and receiver 7 for detecting the signal reflected back from the target. A correlator 8 correlates the reflected signal with the transmitted code, with a selected phase shift corresponding to the current range gate to be tested, whereby the range of the target from the system may be determined. A store 12 contains a plurality of different pseudo random codes, and selector means 13 is arranged to supply to the modulator 2 and to the correlator 8 a code from the store 12 whose breakthrough sidelobe characteristics (Figs.4-6) are suitable for the next range gate or gates to be tested. By choice of the code independence upon range (Fig.7), the effects of the underlobes are eliminated (Fig.8).

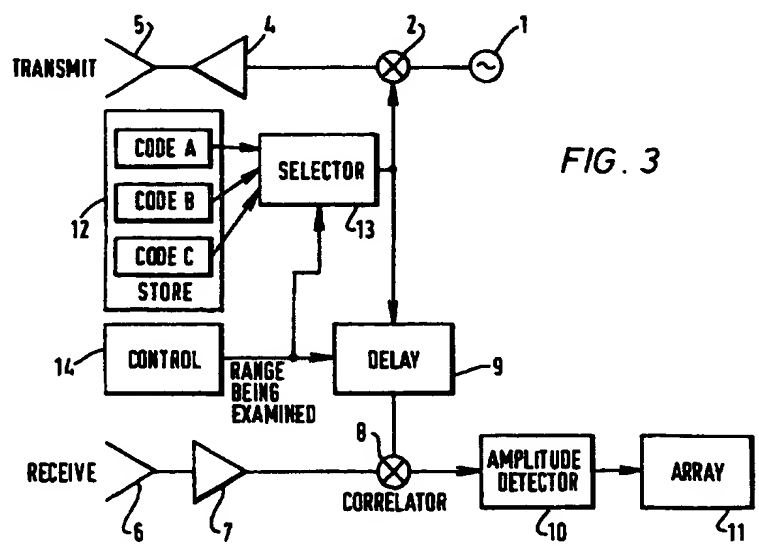


FIG. 3

GB 2 303 754 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

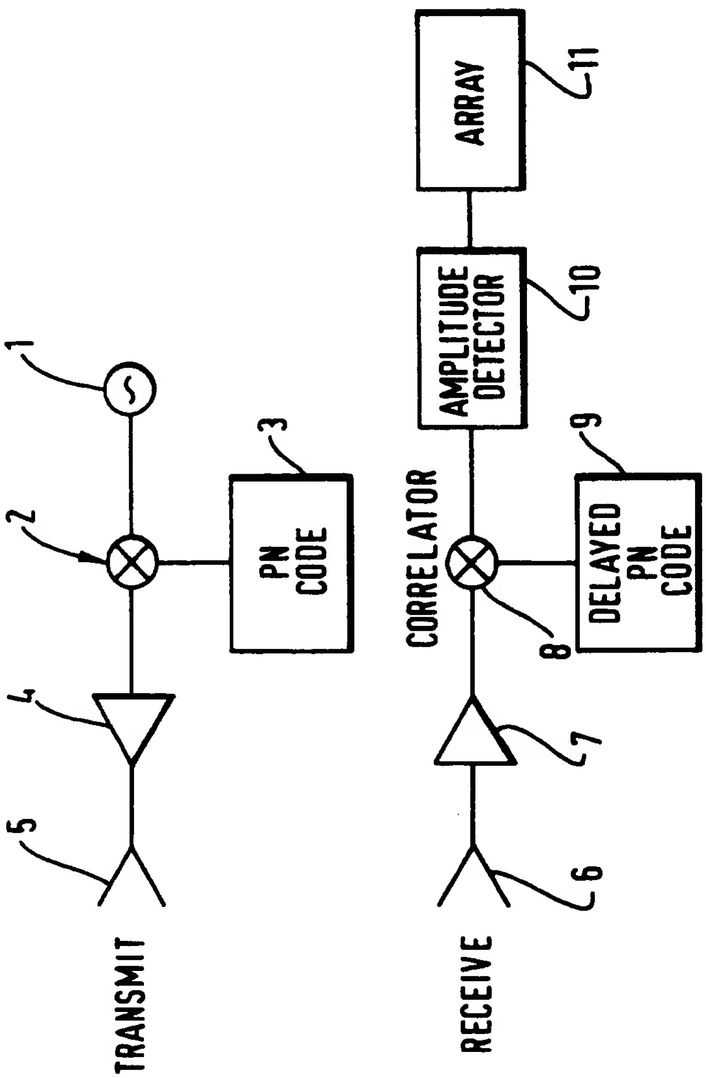

1
2
3
PN CODE
4
5
TRANSMIT
CORRELATOR
8
9
DELAYED PN CODE
7
6
RECEIVE
AMPLITUDE DETECTOR
10
ARRAY
11

FIG. 1

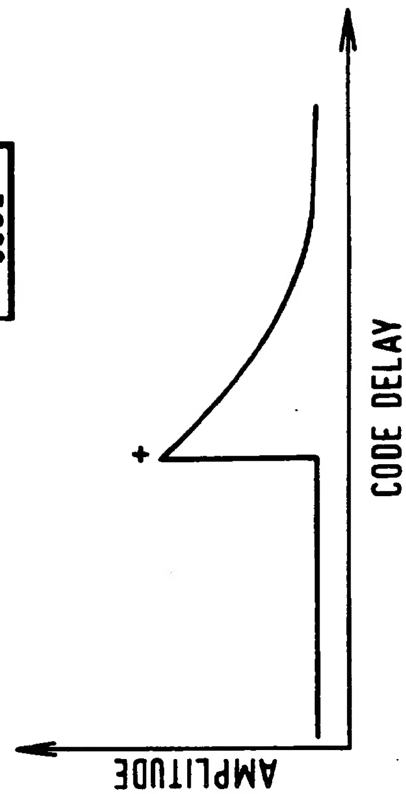

+
AMPLITUDE
CODE DELAY

FIG. 2

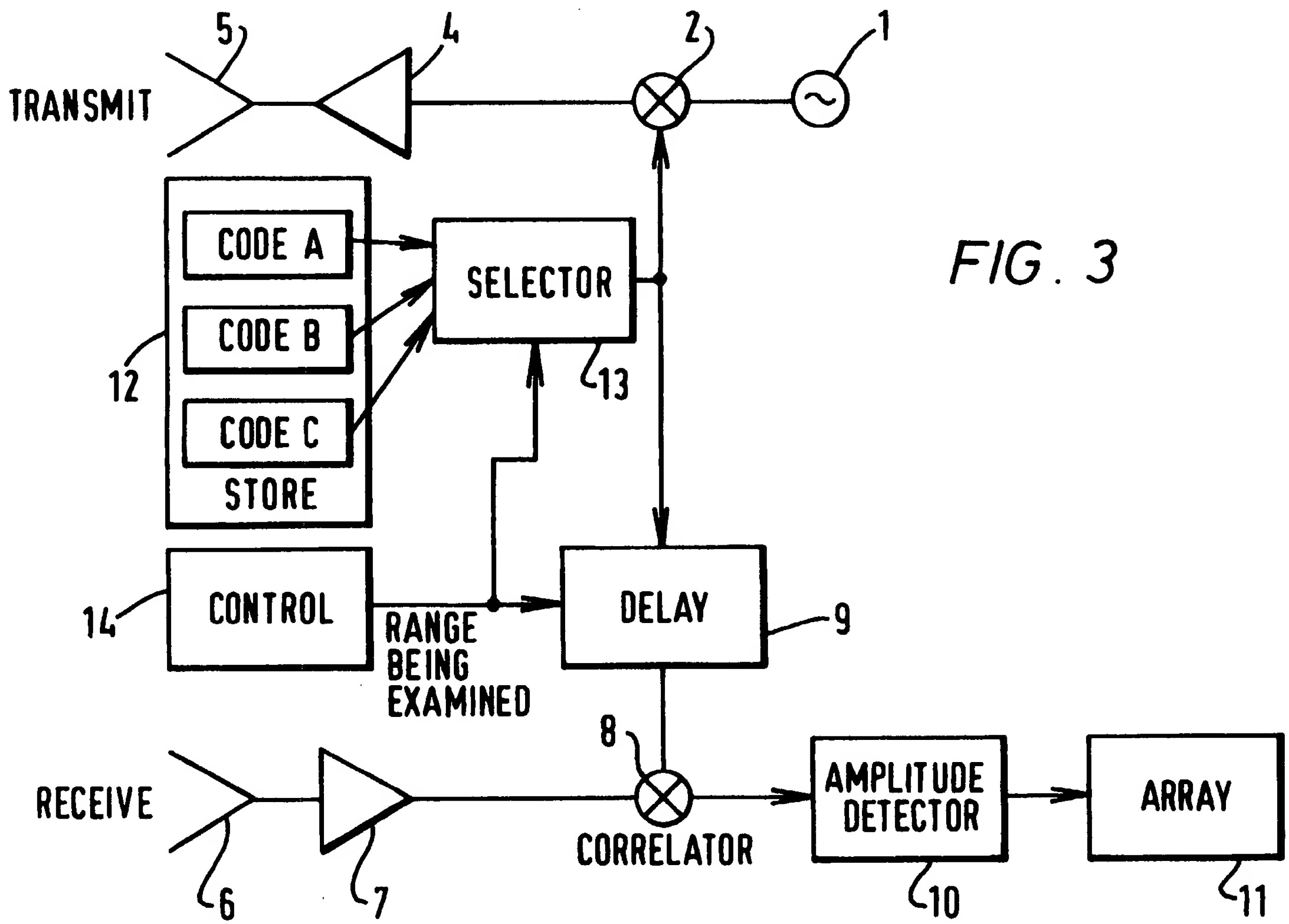

TRANSMIT
5
4
2
1
CODE A
CODE B
CODE C
STORE
12
SELECTOR
13
CONTROL
14
RANGE
BEING
EXAMINED
DELAY
9
RECEIVE
6
7
8
CORRELATOR
AMPLITUDE
DETECTOR
10
ARRAY
11

FIG. 3

3/3

FIG. 4

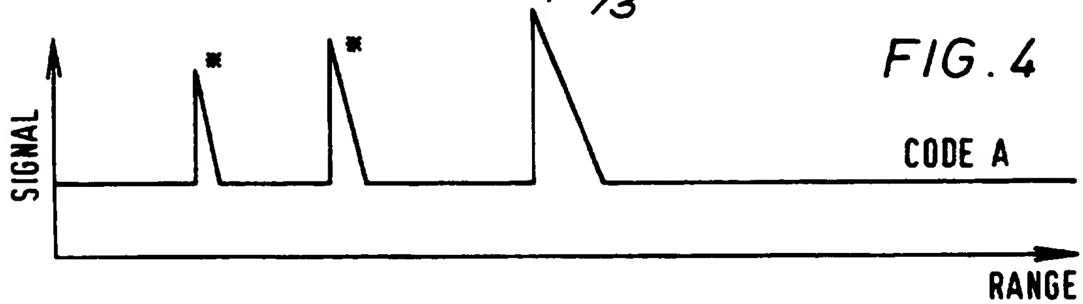


FIG. 5

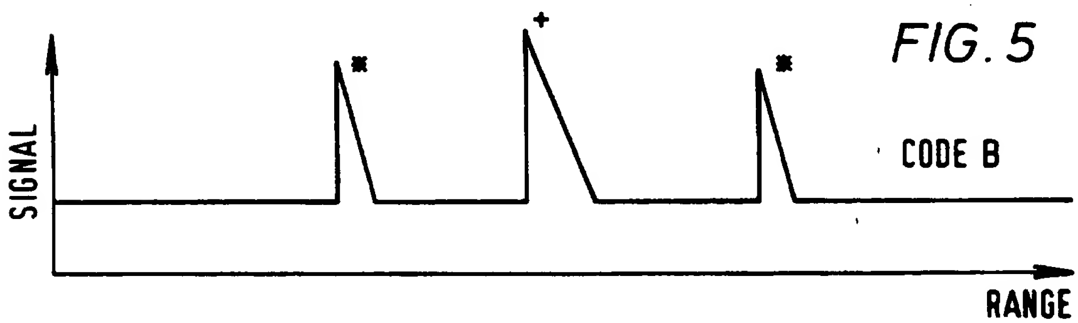


FIG. 6

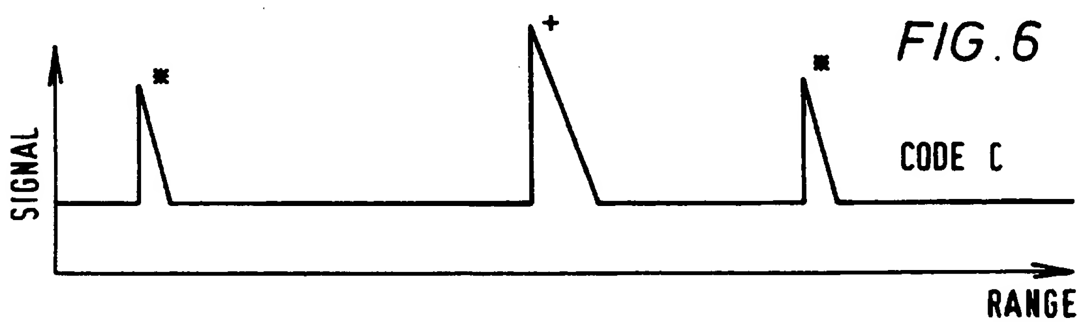
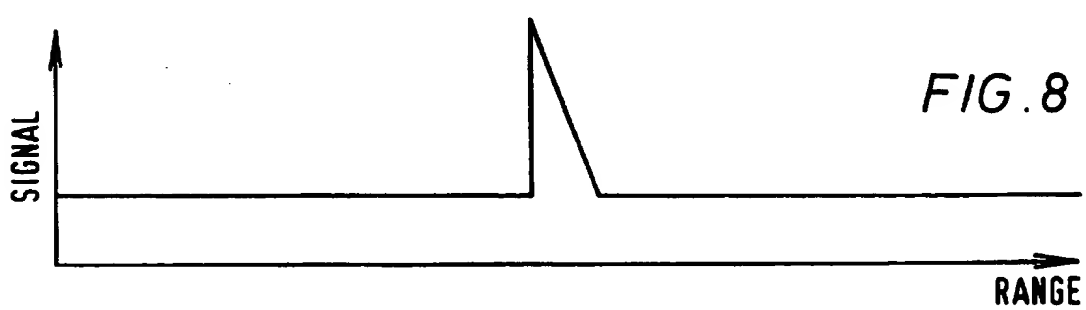


FIG. 7

FIG. 8



2303754

RANGING SYSTEMS

This invention relates to a continuous wave ranging system and, in one aspect, to an aircraft radar altimeter system.

Such systems usually comprise a means of microwave transmission upon which some form of coding has been added, and antenna for directing the energy to the target, an antenna for receiving the returned energy and, after amplification, a means of determining the amount of delay that has occurred on the signal, and hence the range of the target. The coding on the transmission had in the past been pulse or frequency modulation, but more recently phase modulation from a pseudo-random code has been used. This form of modulation has the property of producing a noise-like transmitted spectrum which is difficult to detect and hence finds applications where covertness is of importance. Covertness can be enhanced by reducing the transmitted power such that the returned signal is just sufficient for ranging measurement.

In such phase-modulated systems, the received

signal is correlated with a delayed version of the transmitted code, the delay being gradually increased in steps, and samples of the output of the correlator are detected and stored in an array. From this stored data, the delay, and hence the range, where the received signal return occurs can be found. A typical system is shown in Figure 1 and comprises:- a transmitter including an r.f. signal generator 1; a modulation 2 for modulating the r.f. signal in accordance with a pseudo-random code 3; a transmitter amplifier 4 and a transmitting antenna 5. The receiver includes a receiving antenna 6; a receiver amplifier 7; a correlator 8 for correlating the received signal with a delayed version of the transmitted code corresponding to the range being examined; an amplitude detector 10 and a memory array 11.

The data for such a system is shown in Figure 2, the code delay corresponding to range.

The system shown in Figure 3 uses the same reference numbers as in Figure 1 for corresponding portions of the system. The system shown in Figure 3 differs from that in Figure 1 in respect of the correlation system utilised. In this system, the

received signal is correlated with a selected phase shift on delay 9 corresponding to the range being tested. However, the system also includes a store 12 containing a plurality of different pseudo-random codes and a selector 13 which supplies a suitable code from the store 12 to the modulator 2 and the delay 9 and hence to the correlator 8. The suitable code is selected on the basis of the sidelobe characteristics to be switchable for the range being tested and the selector 12 and delay 9 are both controlled by a controller 14.

In a direct sequence spread spectrum ranging system, correlation sidelobes can appear at any range, due either to the transmitter to receiver breakthrough or to wanted signals. These sidelobe positions can be shown to be related to the position of the signal (breakthrough or otherwise) causing the sidelobe, and the particular pseudo-random code sequence in use. By careful selection of the code sequence, it is possible to achieve a signal to sidelobe performance which allows the sidelobes of wanted signals to be disregarded. However, since the breakthrough signal is usually much greater than any wanted signal, a problem is evident when considering wanted signal to breakthrough sidelobe

levels. Since the breakthrough signal position is constant, it has been found possible for any given code sequence to determine the position of the resulting breakthrough sidelobes.

Accordingly, the invention provides a continuous wave ranging system, comprising a modulator for modulating an r.f. carrier wave in accordance with a pseudo-random code, a transmitting antenna for radiating the modulated signal towards a target, a receiving antenna an receiver for detecting the signal reflected back from the target, a correlator for correlating the reflected signal with the transmitted code with a selected phase shift corresponding to the current range gate to be tested, whereby the range of the target from the system may be determined, a store containing a plurality of different pseudo-random codes, and selector means arranged to supply to the modulator and to the correlator a code from the store whose sidelobe characteristics are suitable for the next range gate or gates to be tested.

The pseudo-random code used in the invention is preferably a maximal length code, a sequence of numbers generated by a shift register with certain feedbacks on

it. For the system of the present invention, a code length of 2047 digits is preferred.

The present invention will now be described, by way of example, with reference to the accompanying drawings in which:-

Figure 3 is a schematic view of a system according to one embodiment of the present invention, and

Figures 4 to 8 illustrate in simplified diagrammatic form plots of signals utilised in the system.

Figures 4, 5 and 6 show in greatly simplified diagrammatic form plots of signal level against examined range cell obtained by correlation for three different pseudo-random codes. The peaks marked with asterisks are the breakthrough sidelobes, while the peak marked (+) is the true signal. Since the position of the breakthrough sidelobes may be determined for any given pseudo random code in any given system, in one aspect of the invention, a range scanning algorithm is arrange to select the use of codes A, B and C to eliminate the effect of the breakthrough sidelobes. The code is

changed only when necessary to minimise the effects of transients on changing code and the delay necessary to allow for the round trip time of the new code to the ground and back. In practice, the code is transmitted repeatedly, and for each sequence received, the code supplied for correlation is either maintained at the same delay for several sequences of code, to filter out the effect of any variations and thereby increase accuracy before stepping onto the next range gate, or the phase shift is incremented for each correlation.

Figure 7 shows in simplified form the sequence of codes selected to avoid the breakthrough sidelobes appearing in the diagrams of Figures 4, 5 and 6. Selection of code B avoids the first sidelobes appearing in Figures 4 and 6, while changing them to code C avoids the second sidelobe in Figure 4 under and the first sidelobe in Figure 5. Finally, changing to code A avoids the final sidelobes in Figures 5 and 6. The resultant response in idealised diagrammatic form is shown in Figure 7.

The code maps themselves are easily implemented by the use of arrays of Boolean variables indexed by range. Each Boolean entry need only signify the suitability of

a particular code for operation in the indexed range. In order to minimise the storage requirements for the resultant code maps, it is desirable that each array element in the map should cover a significant proportion of the entire range, for example 1/20th. Thus each map need only contain 20 values.

In order to minimise the number of code changes made, the scanning algorithm will sometimes need to look ahead when faced with a choice of two or more suitable codes. This look ahead will need to take into account the required scanning order, but if an increasing range scanner is used, then the operation merely involves looking forward through the maps of each suitable code and choosing the one which remains suitable for the longest range. Should two or more codes satisfy this requirement, then the choice is unimportant.

CLAIMS

1. A continuous wave ranging system, comprising a modulator for modulating an r.f. carrier wave in accordance with a pseudo random code, a transmitting antenna for radiating the modulated signal towards a target, a receiving antenna and receiver for detecting the signal reflected back from the target, a correlator for correlating the reflected signal with the transmitted code with a selected phase shift corresponding to the current range gate to be tested, whereby the range of the target from the system may be determined, a store containing a plurality of different pseudo random codes, and selector means arranged to supply to the modulator and to the correlator a code from the store whose sidelobe characteristics are suitable for the next range gate or gates to be tested.

2. A system as claimed in claim 1, wherein a plurality of codes re-selected from the store and used in a sequence which substantially eliminates the effect of breakthrough sidelobes.

3. A system as claimed in claim 1 or 2, wherein the codes are selected on the basis of suitability for

use in future envisaged ranges.

4. A system as claimed in claim 3, wherein the range is scanned increasingly, the codes suitable for the longest ranges can be selected.

5. A system as claimed in claim 3 or 4, wherein the or each code is selected to reduce the number of code changes required when scanning different ranges.

6. A continuous wave system , substantially as described with reference to the drawings.

Amendments to the claims have been filed as follows

1. A continuous wave ranging system, comprising a modulator for modulating an r.f. carrier wave in accordance with a pseudo random code, a transmitting antenna for radiating the modulated signal towards a target, a receiving antenna and receiver for detecting a signal reflected back from the target, a correlator for correlating the reflected signal with the transmitted code with a selected phase shift corresponding to the current range gate to be tested, whereby the range of the target from the system may be determined, a store containing a plurality of different pseudo random codes, and selector means arranged to supply to the modulator and to the correlator a code selected from said store, which code does not provide a breakthrough sidelobe within the next range gate to be tested.

2. A system as claimed in claim 1, wherein a plurality of codes are selected from the store and used in a sequence which substantially eliminates the effect of breakthrough sidelobes.

3. A system as claimed in claim 1 or 2, wherein the codes are selected on a basis of suitability for use

with a plurality of range gates.

4. A system as claimed in claim 3, wherein the range is scanned increasingly and the codes suitable for the largest number of range gates are selected.

5. A system as claimed in claim 3 or 4, wherein the or each code is selected to minimise the number of code changes required when scanning different ranges.

6. A continuous wave system, substantially as described with reference to figures 3 to 8 of the drawings.

Patents Act 1977 12
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
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Relevant Technical fields

(i) UK Cl (Edition K) H4D: DRPB, DRPE, DRPR, DSPS, DSPB, DSPX

(ii) Int Cl (Edition 5) G01S

Search Examiner
G A McLEAN

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI, CLAIMS, INSPEC

Date of Search
23 AUGUST 1990

Documents considered relevant following a search in respect of claims
1 - 6

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
Y	GB 2,202,329 A (BAE) - especially claim 1, page 6	1, 3, 4
Y	GB 1,504,118 A (SIEMENS) - whole document	"
Y	GB 1,246,142 A (ISE) - especially lines 12 - 14, page 1; lines 24 - 34, page 2; lines 27 - 36, page 3; lines 16 - 49, page 9	"
Y	GB 1,140,590 (STC) - especially lines 24 - 27, page 1; line 24, page 3 - line 56, page 4	"
X, Y	US 4,219,812 (USA) - especially lines 37 - 53, column 1; line 67, column 2 - line 10, column 3; line 54, column 3 - line 18, column 4	"

SF2(p)

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(43) Date of A Publication 02.04.1997

(21) Application No 8927422.9

(22) Date of Filing 05.12.1989

(30) Priority Data
(31) 8904884 (32) 03.03.1989 (33) GB

(51) INT CL[6]
G01S 7/03 7/35 13/32

(52) UK CL (Edition O)
H4D DSPB D265 D376 D39X
U1S S1839

(56) Documents Cited
GB 1351096 A GB 1326162 A EP 0020197 A
US 4758839 A US 4012737 A

(58) Field of Search
UK CL (Edition J) H4D DRPB DRPC DRPD DRPM DRPN DSPB
INT CL[4] G01S
Online : WPI, CLAIMS, INSPEC

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(54) **Ranging systems**

(57) A continuous wave ranging system of the type comprising a modulator for modulating an r.f. carrier signal in accordance with a pseudo random code, a transmitting antenna for radiating the signal towards a target, a receiving antenna and receiver for detecting the signal reflected from the target, and a correlator for correlating the detected signal with the transmitted code with a selected phase shift corresponding to the current range gate to be tested, whereby the range of the target from the system may be determined (Figs 1, 2) is provided with filtering means for filtering from the output of the correlator those range gate amplitudes which vary with a frequency less than a predetermined value to discriminate against transmitter breakthrough and local reflections. The filter, 33-35 functions in I and Q channels to subtract a current return from the running average return. Strong continuous returns may be received in addition (Fig 5). The system may be a radar altimeter.

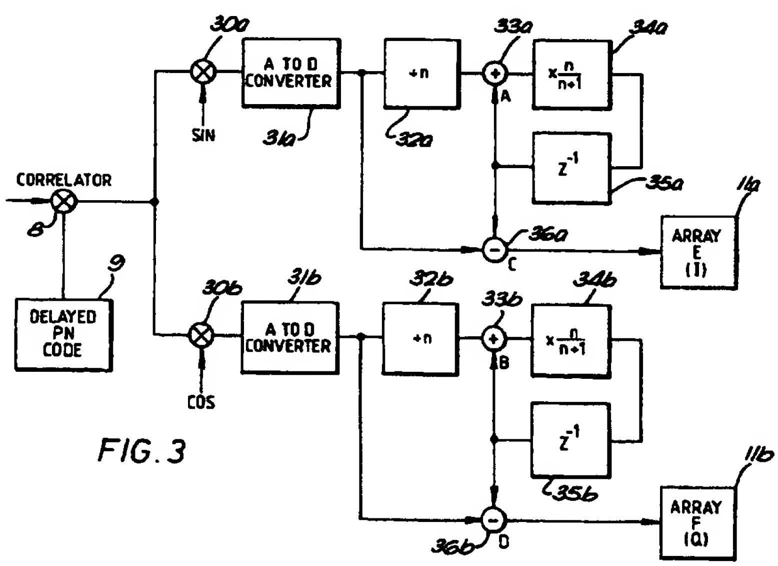


FIG. 3

GB 2 305 323 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

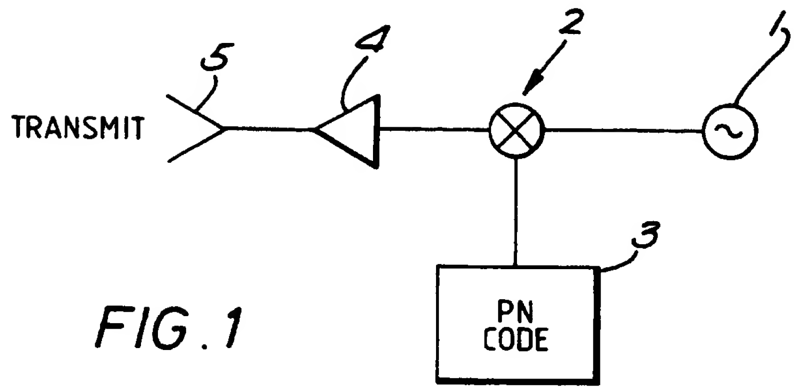

TRANSMIT
5
4
2
1
3
PN CODE

FIG. 1

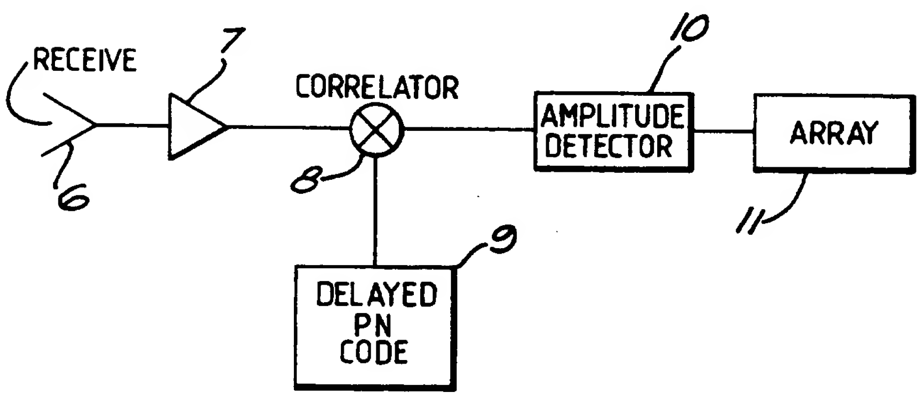
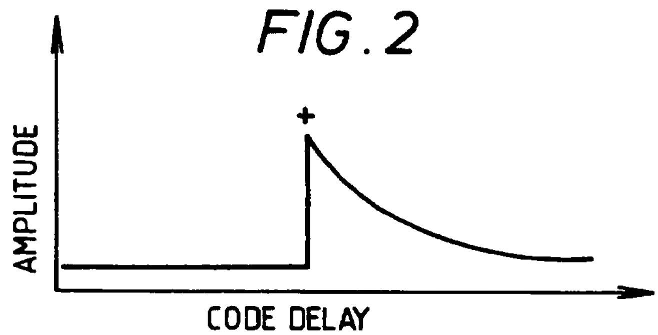
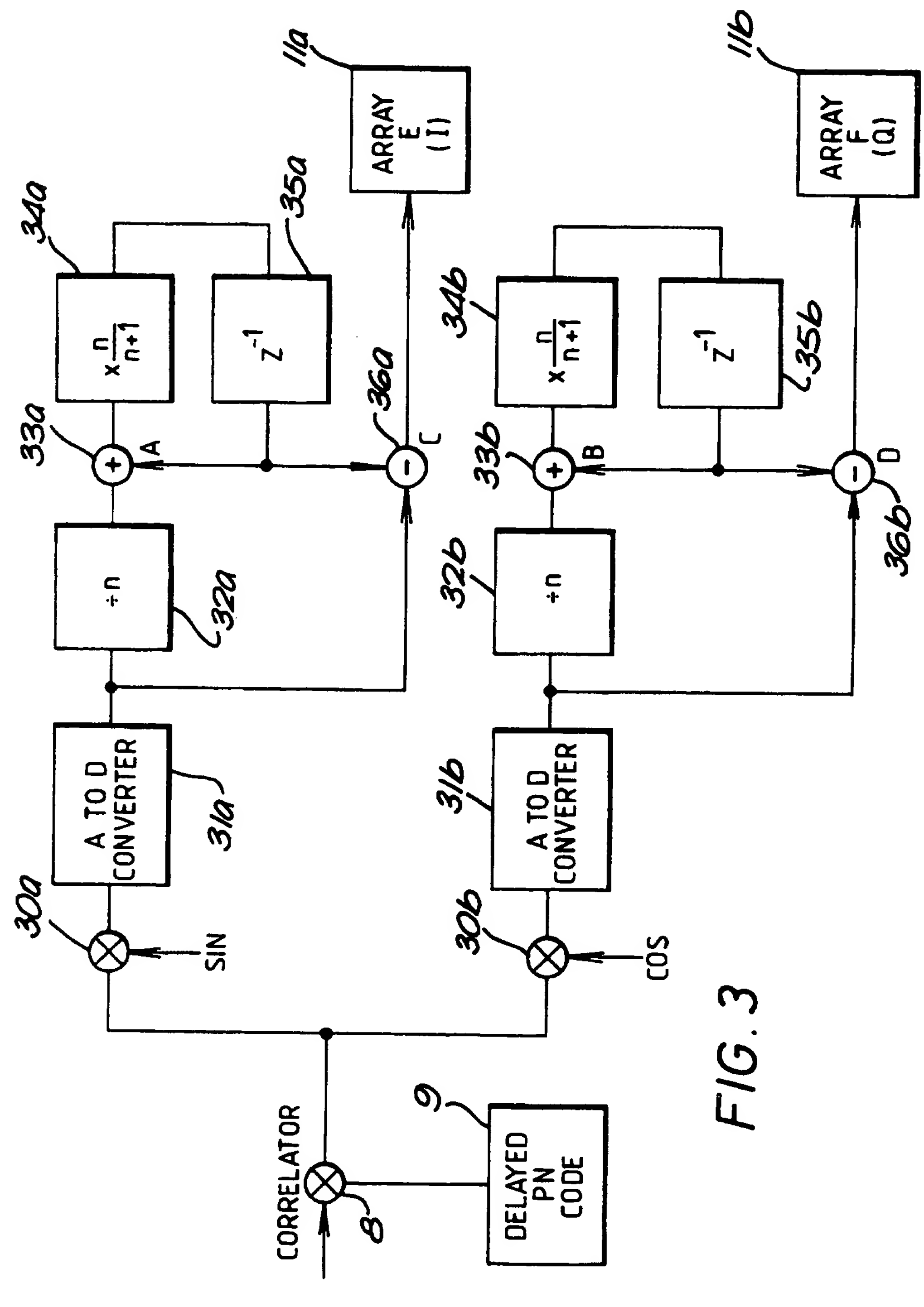

RECEIVE
6
7
CORRELATOR
8
9
DELAYED PN CODE
10
AMPLITUDE DETECTOR
ARRAY
11

FIG. 2

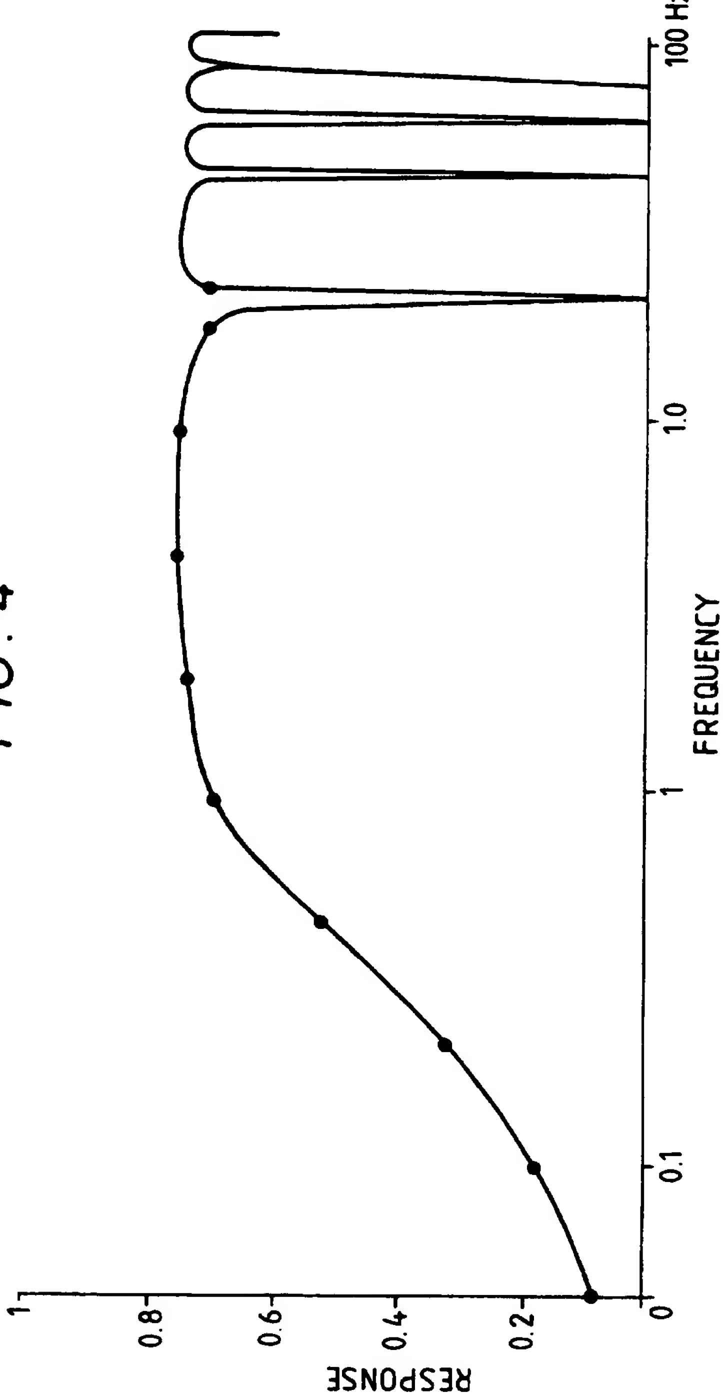

+
AMPLITUDE
CODE DELAY



ARRAY E (I)
ARRAY F (Q)
x n/(n+1)
Z^-1
÷n
A TO D CONVERTER
SIN
COS
CORRELATOR
DELAYED PN CODE
A
B
C
D
11a
11b
34a
35a
34b
35b
33a
36a
33b
36b
32a
32b
31a
31b
30a
30b
8
9

FIG. 3

FIG. 4



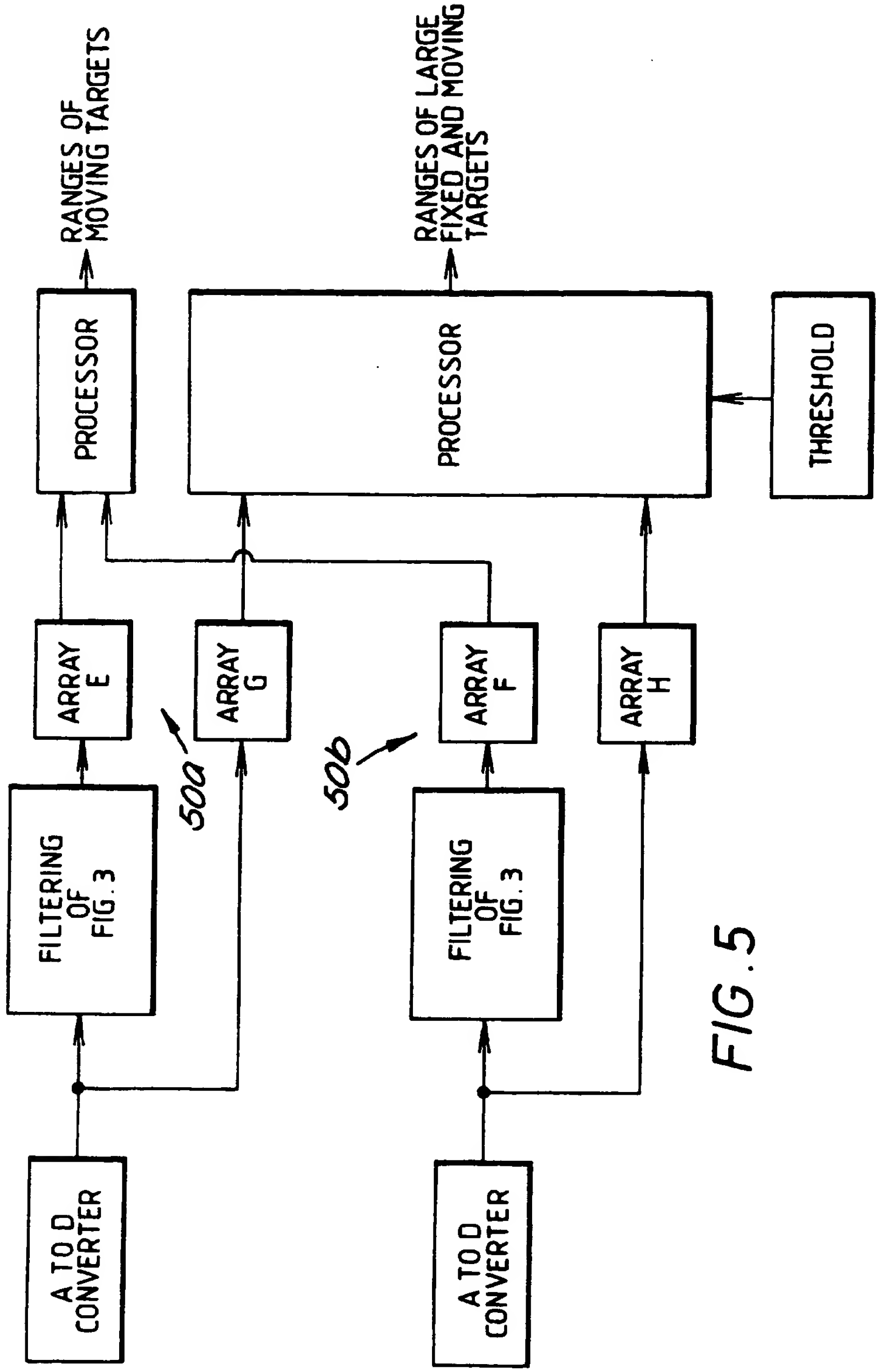

RANGES OF MOVING TARGETS
RANGES OF LARGE FIXED AND MOVING TARGETS
PROCESSOR
PROCESSOR
THRESHOLD
ARRAY E
ARRAY G
ARRAY F
ARRAY H
500
50b
FILTERING OF FIG. 3
FILTERING OF FIG. 3
A TO D CONVERTER
A TO D CONVERTER

FIG. 5

2305323

RANGING SYSTEMS

This invention relates to a continuous wave ranging system and, in one aspect, to an aircraft radar altimeter system.

Such systems usually comprise a means of microwave transmission upon which some form of coding has been added, and antenna for directing the energy to the target, an antenna for receiving the returned energy and, after amplification, a means of determining the amount of delay that has occurred on the signal, and hence the range of the target. The coding on the transmission had in the past been pulse or frequency modulation, but more recently phase modulation from a pseudo random code has been used. This form of modulation has the property of producing a noise-like transmitted spectrum which is difficult to detect and hence finds applications where covertness is of importance. Covertness can be enhanced by reducing the transmitted power such that the returned signal is just sufficient for ranging measurement.

In such phase-modulated systems, the received

signal is correlated with a delayed version of the transmitted code, the delay being gradually increased in steps, and samples of the output of the correlator are detected and stored in an array. From this stored data, the delay, and hence the range, where the received signal return occurs can be found.

A common problem with such ranging systems is that there is often a relatively high level of unwanted signal that is cross-coupled directly from the transmitter to the receiver antenna, or which is reflected from structures around the antenna. Typically, this unwanted signal is 60 dB down on the transmitter output power, whereas the wanted signal from a remote object, or from the ground in an altimeter application, is 120 dB down. Pulse modulated systems may overcome this to some extent by blanking the receiver for a period when the transmitter is pulsed on, but this results in degradation of the short range performance. The system according to one aspect of the invention substantially reduces this problem.

According to the invention, a continuous wave ranging system comprises a modulator for modulating an r.f. carrier signal in accordance with a pseudo random

code, a transmitting antenna for radiating the signal towards a target, a receiving antenna and receiver for detecting the signal reflected from the target, a correlator for correlating the detected signal with the transmitted code with a selected phase shift or delay corresponding to the current range gate to be tested, whereby the range of the target from the system may be determined, and filtering means for filtering from the output of the correlator those range gate amplitudes which vary with the frequency less than a predetermined value.

The invention is based upon the appreciation that a signal coming directly from the transmitter will be substantially constant in phase and amplitude, whereas one from a distant moving object or the ground in the case of an altimeter application, will vary due to the relative movement, which in the case of microwave transmission need only be of the order of a few millimetres.

Preferably, the system of the invention differentiates between fixed and moving returns by using twin channels (in phase and quadrature) on the output of the correlator. Each channel has an output for each of

the delay steps of the correlator. For a given range gate, and thus delay, the outputs from I and Q are compared with results obtained from the running average of several previous readings of the particular range gate. The latest sample is subtracted from the I and Q averages. For a steady signal, the result is zero and thus filtering of steady signals from cross-coupling, for example, is achieved.

In a direct sequence spread spectrum ranging system, correlation sidelobes can appear at any range gate due to the transmitter-to-receiver breakthrough, or to wanted signals. The amplitude of the sidelobes is a function of, amongst other things, the amplitude of the breakthrough or wanted signal. With breakthrough being as much as 60 dB greater than the wanted signal the sidelobes due to the breakthrough can exceed the wanted signal. However, the sidelobes of the breakthrough will also be substantially constant in phase and amplitude and thus the system of the invention differentiates against them as well as the main fixed return.

To be effective the breakthrough must be constant for each range gate and must not be caused to vary by means of transmitter power control. Because each range

gate is treated independently, this can be achieved by varying the power as a function of range gate only. Such a power control system overcomes the response time problems inherent in one relying on sensing returned signal levels and is less complicated than using logarithmic amplifiers.

With the process being carried out digitally, it is possible to include means whereby not only moving signals can be selected, but also fixed signals may be detected if they exceed a given level. For this to be achieved, a further set of processing would be carried out on the received signals after conversion to a digital format. These signals would be passed directly to secondary array without subtraction of the running average. The secondary array will then contain the levels of the returned signals for each of the code delays, irrespective of whether they were moving or not. The level of the return for breakthrough for each delay would be measured in the absence of true signals and this would form a threshold. Genuine signals from fixed targets could be detected if they exceeded this threshold. Such an arrangement would, for example, enable large fixed signals from the ground to be detected in the case of an altimeter whilst an aircraft

was stationary on the ground. The ability to detect and measure the range of large signals complements the ability to measure moving targets in the presence of breakthrough.

The pseudo random code used in the invention is preferably a maximal length code, a sequence of numbers generated by a shift register with certain feedbacks on it. For the system of the present invention, a code length of 2047 digits is preferred.

Reference is made to the drawings in which:

Figure 1 is a simplified diagram of a continuous wave ranging system of the general type with which aspects of the present invention are concerned;

Figure 2 illustrates the data stored in the array of the apparatus shown in Figure 1;

Figure 3 is a diagrammatic illustration of the receiving and processing portion of a system in accordance with one aspect of the invention;

Figure 4 is a diagram illustrating the response

obtained with the system as shown in Figure 3; and

Figure 5 illustrates an optional modification of the system shown in Figure 3.

A continuous wave ranging system using phase modulation with a pseudo random (pn) code is illustrated by Figure 1. The transmitting side has an r.f. carrier wave generator 1 supplying a phase modulator 2 controlled in accordance with a pn code from a code store 3. The modulated signal is amplified by an amplifier 4 and passed to a transmitting antenna 5. The receiving section comprises a receiving antenna 6, a receiving amplifier 7, and a correlator 8 supplied with the same pn code via a variable delay 9 which permits the code to be phase shifted by one digit, corresponding to a specific range, sequentially. A code may thus be considered as being divided into a series of "range gates" corresponding to the separate digits of the code and representing a distance step equal to the maximum range divided by the number of digits in the code, for example 2047. Generally, the code may be phase shifted or delayed significantly in steps of one digit of the code or fractions of a digit. Every value of delay stepped through represents a given range code and the

output of the correlator of each step is a function of the returned signal from that given band of length or range gate. The maximum range is dependent on, inter alia, the length of the code sequence. The results of the correlation are passed to an amplitude detector 10 and are stored in an array 11. The stored data is as shown in Figure 2 and shows the delay where the received signal return occurs (+).

Referring now to Figure 3, the delay of the pn code to the correlator is stepped cyclically over all the range gates to be examined. For each delay the output from the correlator is split into two channels and is mixed at 30a and 30b respectively with a sine and a cosine waveform to obtain the in-phase (I) and quadrature (Q) components of the energy received from targets at the range being examined. Analogue to digital converters 31a and 31b respectively convert the I and Q channels from analogue to a digital level, and from this point onward all processing is in digital form. The level of the current sampled received signal of a particular delay is divided at 32a and 32b respectively by n and added to a running average of previous samples of the same delay factored by n/(n+1). The addition is performed by adders 33a and 33b

respectively, the factoring is carried out in stages 34(a or b respectively) and the running average is stored at 35a and 35b respectively. The running average represents the steady state components of a returned signal from a given range. The latest sample of the returned signal is subtracted at 36a and 36b respectively from the averages (I and Q). For a steady signal from cross-coupling or returns from a nearby structure, the cancellation at 36a and 36b would be complete and no output would be passed to the array. However, if the received signal varies from sample to sample, as will be the case for signals from a moving target, cancellation is not achieved and outputs pass to the array 11a and 11b respectively. In this way, the processing acts as a high pass filter with a response set by the value of n. The effect of the sampling is to place notches at the sampling frequency and at harmonics thereof. The overall response for such an arrangement is illustrated in Figure 4, wherefore this example n is 7 and the sampling frequency 20Hz. It can be seen that considerable attenuation is applied to steady "DC" signals and to signals of up to 0.1Hz. After a complete cycle of samples has been taken, the array contains information of the levels of moving signals for each of the ranges being sampled, whilst rejecting steady

unwanted signals from breakthrough.

A modification to the system illustrated in Figure 3 is illustrated by Figure 5. A further set of processing is carried out on the received signals after conversion to a digital format. The signals are passed directly to secondary arrays 50a and 50b respectively without the subtraction of the running average. The secondary array 50a or 50b then contains the levels of the return signals for each of the code delays irrespective of whether they were moving or not. The level of the return from breakthrough for each delay would be measured in the absence of true signals and this would form a threshold.

CLAIMS

1. A continuous wave ranging system, comprising a modulator for modulating an r.f. carrier signal in accordance with a pseudo random code, a transmitting antenna for radiating the signal towards a target, a receiving antenna and receiver for detecting the signal reflected from the target, a correlator for correlating the detected signal with the transmitted code with a selected phase shift corresponding to the current range gate to be tested, whereby the range of the target from the system may be determined, and filtering means for filtering from the output of the correlator those range gate amplitudes which vary with a frequency less than a predetermined value.

2. A system according to Claim 1, wherein the output from the correlator comprises twin channels, for phase and quadrature signals.

3. A system according to Claim 2, comprising an analogue-to-digital converter for each channel.

4. A system according to Claim 1, 2 or 3, wherein the filtering means comprises means for establishing a

running average of the or each output, and means for subtracting the current output from the running average.

5. A system according to Claim 3, wherein a further processing stage is provided to receive digital signals from the analogue-to-digital converter, the further processing stage comprising a store array for each channel arranged to store the returned signal for each code delay in the absence of the signals to establish a threshold, and means for comparing subsequently received signals with the threshold value to detect signals exceeding the threshold value.

6. A system according to any preceding claim, comprising means for varying the power of the signal radiated as a function of the range gate being tested.

7. A continuous wave ranging system, substantially as described with reference to the drawings.

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Examiner's report to the Comptroller under Section 17 (The Search Report)

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Relevant Technical fields

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Search Examiner

G A McLEAN

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI, CLAIMS, INSPEC

Date of Search

15 JUNE 1990

Documents considered relevant following a search in respect of claims 1 - 7

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X, Y	GB 1,351,096 A (HONEYWELL) - especially lines 17-49, page 1; line 73, page 2 - line 55, page 3	1-3, 6
X, Y	GB 1,326, 162 A (ISE) - especially lines 15-68, page 1; lines 104 - 115, page 2, Figure 1	"
X, Y	EP 0,020,197 (THOMSON) - especially lines 9-26, page 2; line 23, page 4 - line 28, page 5	"
Y	US 4,758,839 (McDONNELL) - whole document	"
X, Y	US 4,012,737 (ITT) - especially line 6, column 4 - line 8, column 5	"

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